SCIENCE

FRIDAY, JUNE 18, 1909

CONTENTS

The Physics Teacher's Problem: PROFESSOR C. R. MANN ... 951

Albert B. Porter: PROFESSOR HENRY CREW ... 962

Banquet in Honor of Professor Bessey ... 963

British Association Trip to Alaska ... 964

The Carnegie Foundation for the Advancement of Teaching and the George Washington University ... 964

Scientific Notes and News ... 965

University and Educational News ... 969

Discussion and Correspondence:—

Minimal Quantities of Preservatives: PROFESSOR J. F. SNELL. *The Chalk Formations of Northeast Texas:* DR. ROBT. T. HILL. *The Daylight Saving Bill:* T. C. M. *Library Book-stacks without Daylight:* DR. W. W. KEEN ... 970

Scientific Books:—

Recent Mathematical Books: PROFESSOR C. J. KEYSER. *Gilman's Hopi Songs:* ALICE C. FLETCHER ... 974

Special Articles:—

The Dorsal Spines of Chameleo cristatus Stuch: PROFESSOR E. C. CASE. *On the Chemistry and the Development of the Yolk Platelets in the Egg of the Frog:* DR. J. F. MCCLENDON. *The Structure of Lily Pistils:* CHARLES E. TEMPLE ... 979

Societies and Academies:—

The Iowa Academy of Science: L. S. ROSS. *The Torrey Botanical Club:* PERCY WILSON 980

MSS. intended for publication and books, etc., intended for review should be sent to the Editor of SCIENCE, Garrison-on-Hudson, N. Y.

THE PHYSICS TEACHER'S PROBLEM[1]

THAT physical science is constantly rendering most magnificent service to human life was never more dramatically demonstrated than on the occasion of the recent wreck of the steamship *Republic*. That a ship, disabled and hidden in a dense fog, was yet able to summon to its aid another ship a hundred miles away by an inaudible, invisible, yet infallible means of communication, thereby saving many hundred lives, is a feat that would have been pronounced impossible by our grandfathers if not by ourselves but a few years ago. Had Mr. Binns, the operator of the wireless telegraph on the *Republic*, lived near Boston about two hundred and twenty years ago, he would surely have been burned for witchcraft.

So thick and fast have come such contributions of science to our commercial and economic life, that most people now take them as a matter of course. A telephone is at present almost as much of a household necessity as a kitchen stove. The steam engine and the electric motor, since by their aid ten men can do the work of one hundred, are increasing our potential manufacturing population at a rate that must satisfy even President Roosevelt that we are in no immediate danger of dying out as a nation. Musicians are being replaced by arc lights, or by pianolas; and even teachers are being compelled to yield their divine calling to graphophones in the "teaching" of foreign languages. Are we then surprised that this is called a scientific age? Do we wonder that scientists are

[1] Address delivered at the Fourth Annual Conference of the Schools of Vermont with the University of Vermont, March 12, 1909.

deeply fascinated by their work, or that the public stand in awe of it?

Yet in the midst of all this, our glory, we must not fail to pause now and then to recall that story of that greatest of astronomers, Laplace. When he had reduced the cosmos to a set of differential equations, by which he claimed that he could foretell the configuration of the universe at any time if he had given the configuration at some other time, he presented his work to Napoleon. After listening to an exposition by Laplace of the meaning of the work, Napoleon remarked: "But I see no place for God in your system." To which Laplace replied: "Sire, I have no need of such an hypothesis."

Suppose some modern Napoleon should, after examining the present formulations of scientific creed, remark: "But I see no place for human souls in this system"; what could science answer? Much it has surely done for the human body; what has it done—what is it doing for the human soul?

A careful investigation of this question seems to show that the distinctive services of science to the human soul may be resumed in two statements, namely: (1) In developing science through the study of nature, the human mind has been trained in clear thinking—it has learned how to solve problems in such a way as to gain for itself the keen vision of a prophet. (2) The clear-sighted experimental study and the partial solution of the problems of nature have continually stored the mind with images which are definite because drawn from concrete experience, and which may thus serve as the basis for clearer abstract thought.

The first of these statements will probably be accepted at once. We all recognize that the power to foresee what will happen under given conditions is one of the chief benefits derived from scientific thinking; and, therefore, we find no difficulty in appreciating the value of a training in this method of thought. The second statement may not be accepted so readily. Yet it must be clear that such basal concepts as angle, area, number and triangle were derived from experience with and the solving of the problems of nature. The idea means more than this, however. The concrete pictures furnished by the solution of scientific problems are essential to clear thinking in other fields than those of science. It has often been said that if no regularity or order were manifested in nature, no thinking at all would be possible. The clear picture of a sequence and order in nature, yet independent of man's will, is of inestimable moral value. So many of us think that we may steal or lie and yet somehow evade the results. Natural science gives a very definite picture of the impossibility of this. The concrete picture of the sun-centered planetary system has been indispensable in the development of the idea of a God-centered religion. Was not Drummond's book called "Natural Law in the Spiritual World"? Are not most of the similes and metaphors of literature to-day drawn from the clear images furnished by science?

If the two statements just given set forth the two great contributions of science to the civilized mind of to-day, we are justified in setting them up as expressing the purposes to be attained in the individual by science teaching in the schools. We may thus define the purposes of science teaching to be the following: (1) To train the individual into habits of solving problems scientifically, thereby fostering the prophetic spirit in him. (2) To store his mind with clear pictures of organization, which pictures may be used as the basis of abstract thought.

Having adopted these two purposes as the ideal toward which we are to strive in

our teaching of science, we must ask: What criteria have we for testing the results of the work? How are we able to tell whether we are approaching the attainment of these purposes with our teaching? There are two questions which we may put to ourselves if we wish to test our success in attaining these purposes—one for each purpose. First we must ask: Did the problem arise within and out of the student's own experience so that he has a genuine interest in its solution? Is it in some way vitally connected with his life, so that he has an inner motive for its solution? Unless this condition is met, unless the student has real interest in the work put before him, he will get no real training and discipline from it.

The importance of this point has been made very clear by Professor John Dewey in his paper on "Interest as Related to Will"—a paper which has been justly called a supreme court decision on this matter. Professor Dewey says (page 32):

> Just because interest is an outreaching thing, a thing of growth and expansion in the realization of impulse, there can be no conflict between its genuine utilization and the securing of that power and efficiency which mark the trained mind—which constitute real "discipline." Because interests are something that have to be *worked out* in life and not merely indulged in themselves, there is plenty of room for difficulties and obstacles which have to be overcome, and whose overcoming forms "will" and develops the flexible and firm fiber of character. To *realize* an interest means to *do* something, and in the doing resistance is met and must be faced. Only difficulties are now intrinsic; they are significant; their meaning is appreciated because they are felt in their relation to the impulse or habit to whose outworking they are relevant. Moreover, for this reason there is motive to gird up one's self to meet and persistently to deal with the difficulties, instead of getting discouraged at once, or half-consciously resorting to some method of evasion, or having to resort to extraneous motives of hope and fear—motives which, because external, do not train "will," but only lead to dependence upon others.

What a different picture this gives from that drawn by those who think interest means amusement; and who, therefore, drive their students by means of motives of hope or fear through unrelated quantitative experiments with the idea that they are giving them discipline!

The second question that we should ask in test of our work is: Are the concepts with which the student is working clear to him? Is the final picture clear, so that clear thinking on his part has been possible? This question needs no further explanation.

Each teacher must answer the first of these questions for himself; no outside person can possibly answer it for him, nor can it be settled by either examination or inspection from the outside. Speaking for myself, then, I may say that for more than three quarters of every class I have, I must answer it in the negative. The majority of each class is attending and pretending to work because of some secondary motive—a college requirement, a desire for credits with a minimum amount of work, a wish to fill an hour in the program, or something of the sort. Comparatively few are there because of an inner interest that impels to good work; and many who might become interested are repelled by the fact that the course is cut and dried, the experiments set up so as to give the student a minimum of obstacles to overcome and a minimum of thinking to do. The testimony of a large number of my colleagues has led me to the belief that this condition is very general—that there are few, if any, teachers whose class as a whole is working spontaneously from genuine interest as defined above. The added testimony of a large number of high-school principals and college deans, who assist the students in the selection of their courses, has made me believe that a large majority of the students shun science courses whenever possible; not because they

are "hard," but because they offer them no chance of expressing their own inner self in new materials—of molding their environment to their scientific imaginations.

The second of these questions above—that concerning the clearness of the concepts—may be answered, at least superficially, by examinations and inspection; and the answer is an unequivocal *"no."* I am sure that every teacher of physics will agree with me when I say that an examination paper on which there is no utterly foolish statement is a great rarity. The questions asked in class show the same lack of clearness, as has been very forcibly shown by Mr. H. L. Terry in the *Educational Review,* January, 1909. Has any one found a means of making the students discriminate clearly between force, work and power, for example? Here are some examples of what is meant, taken from some recent prize examination papers submitted in competition for a scholarship at the University of Chicago. The competitors were the best students in neighboring high schools. "According to Archimedes' principle, the buoyant force of the water is equal to the volume of the water displaced." "Work is the amount of force that is spent on a certain object, neglectful of time." "Efficiency of a machine is the amount of power received divided by the amount of force exerted upon it." "By Archimedes' principle a body displaces its own weight in water." "The wave-length of red light is longer because in the aurora red light stands out more than does green light."

The fact that from 60 to 70 per cent. of the candidates in physics fail to pass the written examination of the college entrance board each year is eloquent testimony to the same effect.

As the result of a long and careful study of this subject, I can not myself avoid the conclusion that the teaching of physics is not having even a fair degree of success in attaining the purposes stated above. Any one who accepts these purposes as his ideal, must, I believe, concur in this opinion. That others may have other ideals and purposes in teaching physics, has been abundantly shown by the work of the physics commission. In Circular III.[2] we find that 130 teachers suggested 28 different purposes of teaching physics; some suggesting more than one, but not more than 30 agreeing on any one. Thus some few avow that passing examinations is their purpose: others make "mental discipline" the fundamental aim—meaning thereby the teaching of students to do what they do not want to do because they will have to do so the rest of their lives: thus only may physics become a preparation for grim life. Still others may have the end of teaching the laws and principles of physics; by which is meant bringing the student to the point where he is able to recite and write the statements of these laws, even though he may not be able to show that he possesses clear concepts of the physical quantities related by the laws, or of the relations they describe. Thus he who has other purposes in teaching science may justly believe that physics teaching is satisfactory; but he who accepts as his highest ideal the purposes stated above, must acknowledge that the greater part of physics teaching at the present time fails, to a greater or less extent, to attain those purposes. The teaching of physics is not on that account useless altogether: it is only that it might be a real creative power in education instead of a mere adjunct.

The physics teacher's problem is now before you. It may be stated thus: How shall courses and instruction be modified so as to make the work more nearly approach to the teaching purposes? We teachers

[2] *School Science and Mathematics,* November, 1906.

shall, of course, have to solve this problem by experiment. We have got to learn first of all to apply the methods of our subject to our teaching problem; we must each and all of us preserve a frankly open-minded and questioning attitude toward our work, and be ever ready to experiment and to make changes in our methods when we find them faulty. We must not cease asking ourselves test questions like those given above, and should regard the students as our real materials for investigation.

But the problem before us, as thus far stated, is too general and vague. We must be more specific, and show just where improvement is most needed. Before making the problem more specific, I want to point out that there are two serious obstacles that confront every teacher who wishes to undertake experimental scientific work along this line. One of these obstacles is an administrative one, due to the school system in general; this obstacle is controlled by forces outside the teacher. The other is a psychological obstacle, due to the past habits of the teacher himself; and to the failure on the part of teachers generally to have definite notions of the meanings of words like interest, discipline, qualitative, quantitative, mathematical, abstract, physics, law, principle and so on.

Time forbids that we discuss these obstacles in detail. Yet they must be removed before the physics teachers will be free to attack their real problem effectively. I will merely state specifically what they are and what is being done to remove them. The first obstacle consists in the systems of regulations that exist for the purpose of securing uniformity of work, whether for college entrance or otherwise. They are not aimed at securing uniformity of good teaching—if they were, there would be no complaint. They attempt to secure uniformity of subject matter. To any one who studies the system from the point of view of educational value to the individual student, it can not fail to appear injurious and subversive of the ends it tries to reach, namely, vital study. It makes but little difference whether such systems are maintained by examination, or by accrediting, or by state law. The injury comes from the fact that the subject matter of the course of study is specified in minute detail by some authority outside the school and hence unfamiliar with local conditions, particularly the motives and interests of the particular students concerned. The outside authority may be either a board of regents, a committee of some association or a group of colleges, without in any way lessening the evil effect of seriously hampering the teacher in the use of his own initiative and in his attempts to meet local and individual needs. A certain degree of uniformity is certainly desirable; but a bare outline of the larger phases of the subject suffices for this, and avoids the very grave injury that is sure to result to the students from a long and detailed syllabus enforced by an authority outside of the school.

Perhaps the best statement of the fundamental fallacy of this strife for uniformity is that given by Professor Dewey in the pamphlet mentioned above (page 16), when he says:

> I know of no more demoralizing doctrine—when taken literally—than the assertion of some of the opponents of interest that *after* subject-matter has been selected, *then* the teacher should make it interesting. This combines in itself two thoroughgoing errors. On one side, it makes the selection of subject-matter a matter quite independent of the question of interest—and thus of the child's own native urgencies and needs; and further it reduces method in teaching to more or less external and artificial devices for dressing up the unrelated material so that it will get some hold upon attention. In reality, the principle of "making things interesting" means that subjects shall be selected in relation to the child's present

experience, powers and needs; and that (in case he does not perceive or appreciate this relevancy) the teacher shall present the new material in such a way as to enable the child to appreciate its bearings, its relationships, its necessity for him.

This quotation also makes clear why those who believe in extended and detailed syllabi can think of interest only as synonymous with amusement, so that they strive for a supposed discipline which Professor Dewey shows to be subversive of true discipline as follows:[3]

The absurdity of much of the current conception of discipline is that it supposes (1) that unrelated difficulties, tasks that are only and merely tasks, problems that are made up to be problems, give rise to educative effort, or direction of energy; and (2) that power exists and can be trained at large apart from its application.

This first obstacle of administrative systems was considered at length at the recent meeting (February, 1909) of the Department of Superintendence of the National Educational Association by Superintendents Stratton D. Brooks, of Boston; C. E. Chadsey, of Denver; W. E. Chancellor, of South Norwalk; C. P. Cary, of Wisconsin, and R. J. Aley, of Indiana. There was a striking unanimity in their recognition of the injurious nature of present practises. All made constructive suggestions for improvement, and those who are interested in this matter should read their papers, which will be published soon in the proceedings. You should also read the able papers on this topic by Professor J. M. Coulter in the *School Review* for February, and by Professor F. N. Scott in the same journal for January. The Carnegie Foundation for the Advancement of Teaching is devoting considerable attention to this matter, and several state legislatures are considering bills relative to it.

The second obstacle—that of the lack of understanding among teachers of certain terms—is being rapidly removed by the discussions now being held at meetings of teachers' associations and at conferences like this. I am sure we shall soon come to understand each other better, provided all can recognize that the discussion is a wholly impersonal one, carried on solely in the interests of the coming generations. We may therefore pass on to the more definite specification of the real educational problems that now confront the physics teachers.

The first important problem is that of the preparation of the child for science. There is at the present time practically no science in the elementary schools. In the earlier years of the high schools there is very much less science than there should be. Suitable courses in elementary science must be devised for and presented in the earlier years of the elementary schools, in order to store the child's mind with an adequate supply of concrete experience with the materials of science. In solving this part of their problem, physics teachers will have to cooperate with the nature study and the industrial education movements, since it is through these that the elementary basis will be laid. This is the most important and difficult problem. When it is solved, the nature of the high-school course will in large measure be determined; not, as at present, by what may come after, but by what has gone before. The college courses in turn will have been modified to fit the high-school courses, and not the reverse.

The solution of this problem will require much time and a large amount of scientific experiment. In the meantime, we can do much to make the present one-year course in the high school much more efficient than it is in yielding clear and definite concepts and in training in clear thinking. How may this be done?

The chief reason for the present failure

[3] *L. c.*, p. 32.

of the physics course to train in scientific thinking seems to me to lie in the fact that the method of presentation used is thoroughly unscientific. Abstract and difficult concepts in the form of definitions and laws are thrust upon the student without warning, and before his mind is adequately prepared for them by suitable common sense discussions of his concrete experiences—he does not feel their necessity or see their use.

Illustrations of this failing may be taken from any chapter of any of the texts now in use. Thus, the discussion of light is generally introduced by statements concerning the luminiferous ether; properties of matter are introduced in terms of molecules and atoms; heat is explained as a form of energy before its properties are studied. But the most notorious offenses against the scientific spirit of the student are committed in the name of the absolute system of units; they cluster about that tiny and apparently inoffensive thing, the dyne. Unless a student gets a clear conception of what a dyne is, he is lost; because most of mechanics depends on it, in the present method of presenting the subject. Far be it from me to attempt to belittle the dyne—it is little enough already. Nor would I give the impression that the dyne is unessential for the adult physicist, or that the absolute units are not the most beautiful and useful of all the "absolutes" under which the rationalistic mind has sought to hide its real ignorance of reality. The trouble with the dyne in elementary teaching is that it can not be derived directly from experience. It depends for its definition on a convention that can not be verified by experience. The student can, of course, learn to recite the definition of the dyne, or even to write the formula that expresses this definition; and, by mechanical substitution in this formula, he may be able to solve abstract problems—problems that are made up to be problems, but that can not be realized in practise or related to experience. He can not visualize the dyne, nor form a concrete image of it—an image that is derived directly from experience and that is therefore usable in clear thinking.

To a beginner pushes and pulls are the real forces. He can appreciate their measurement by elastic springs, and their comparison in terms of pounds or grams weight. He can not, as a rule, appreciate the measurement of force in terms of mass-acceleration for three reasons, namely: (1) He has no clear scientific concept of mass and it takes considerable time to acquire it. How many of us teachers would agree on any one attempted definition of mass? (2) He has very imperfect notions of acceleration; and he really can not get a concrete, quantitative picture of this without the calculus. Did not Newton himself invent the calculus before he was able to treat acceleration? (3) In all of his actual experiences with natural phenomena the force balanced by mass-acceleration is small compared with the force balanced by friction and other resistances.

For these reasons it seems to me perfectly clear that the dyne should not be introduced at the beginning of a course in elementary physics. If a second year of work in this subject is given in the high school, the dyne might be introduced then, provided that the first course had been of the right sort; otherwise it must be left for the colleges.

Since the dyne is the actual point of contact—I might appropriately say the mathematical point of contact—between the two opposing pedagogical creeds of physicists, it is very important that we see the point clearly and appreciate its great significance for physics teaching. I, therefore, will adduce some of the arguments that are put forth in favor of retaining the dyne so as

to point out again the psychological fallacy involved. The dyne has been defended in a recent discussion before the Eastern Association of Physics Teachers,[4] as follows:

> First it will be noticed that, as the units of the system are logically derived from the fundamental units, logical reasoning on the part of the pupils will be required. Those educators who contend that the chief work of the physics teacher is to entertain and amuse will not accept this as an argument. Others, however, will take delight in the opportunity afforded for rapid-fire drill and review. Question—What is a watt? Answer—A watt is a unit of power and is equal to a joule a second. Q.—What is a joule? A.—A joule is a unit of work and is equal to ten million ergs. Q.—What is an erg? A.—An erg is the C.G.S. unit of work and is the work done by a force of one dyne acting through one centimeter. These questions can be continued until the pupil has not only shown that he knows the definition of the centimeter, the second and the gram mass, but also that he has a knowledge of what work, force, etc., themselves are.

In reply to this let me point out that reasoning with words which have no concrete content is useless and scholastic. A student may jingle along words like watt, joule, erg, dyne; but, without clear concepts of the meanings of these terms, his logical faculties get no more training than if he were arguing how many devils can dance on the point of a needle. As Mr. H. Poincaré has pointed out ("Essay on the General Definitions of Mathematics"):

> What has been gained in rigor has been lost in objectivity. It is by withdrawing from reality that this perfect purity has been acquired. Demonstrations are constructed by logic, but inventions are made through intuition. To know how to criticize is good; but to know how to create is better. Logic tells us that on such and such a path we are sure to meet no obstacles; but it does not tell us which path leads to the goal. The faculty that enables us to do this is intuition.

Second: I know of no physics teachers who think the work of the physics teacher is to amuse; unless possibly it be those who keep their students loafing over quantitative experiments from which the difficulties have been removed, by logic or otherwise, and which are therefore incapable of giving "discipline" in the true sense defined above.

Third: The string of questions and answers runs along very smoothly on paper—almost as smoothly as The House that Jack Built: This is the dog, that worried the cat, that killed the rat, that ate the malt, that lay in the house that Jack built. To my thinking, this latter is far richer in thought content to the student than is the string about watts, joules, ergs. Such a string of questions may surely be continued till the student has learned the words that are supposed to define the gram mass, but no amount of questioning of this sort will ever lead him to a scientific concept of mass, or to a "knowledge of what work, force, etc., *themselves are.*" Physicists are agreed that knowledge of this sort is useless, even if it were attainable. Thus Poincaré says ("Science and Hypothesis," page 78):

> Even though direct intuition made known to us the real nature of force in itself, it would be insufficient as a foundation for mechanics; it would besides be wholly useless. What is of importance is not to know what force is, but to know how to measure it.

Again (page 73):

> When we say force is the cause of motion, we talk metaphysics, and this definition, if one were content with it, would be absolutely sterile. For a definition to be of any use, it must teach us to *measure* force; moreover that suffices; it is not at all necessary that it teach us what force is *in itself*, nor whether it is the cause of the effect of motion.

In like vein William James says:[5]

> The term "energy" doesn't even pretend to stand for anything "objective." It is only a way of measuring the surface of phenomena so as to string their changes on a simple formula.

At this same meeting of the Eastern Association of Physics Teachers the present es-

[4] Report of the fifty-second meeting of the E. A. P. T., p. 13.

[5] "Pragmatism," p. 216.

sentially rationalistic system was further defended as follows:

Second—It will be observed that the absolute system enables us to define in a simple manner certain physical quantities which can not otherwise be defined without great circumlocution. For example—an unbalanced force always produces some kind of acceleration. How can force be better defined than by the acceleration which it will produce? This being the case, what better unit of force can be employed than one which will give a unit mass a unit acceleration? $F = ma$ is the simplest possible statement of the measure of a force and one which, if the pupil understands acceleration, will greatly assist him in obtaining some conception of force.

To the first of these statements I will let Professor John Perry, the leader of the reform movement in England, answer:[6]

There is too much hankering after a kind of logical perfection which is impossible in the teaching of the average boy. I am afraid that what seems to you simple is to him complex, and what seems to you complex is to him quite simple. As a result, you have not made his studies as interesting to him as you might, and whatever is uninteresting to him is uneducational.

I may add that clear definitions grow out of experience, and by teaching word definitions that have not been justified in advance by experience, we are but training in the habit of hiding our ignorance of things under high-sounding words.

To the second statement about the simplicity of the definition of force I would remark: "Certainly." But I would place the emphasis where the writer did not intend it, namely, on the clause "If the pupil understands acceleration." I must also add: "and if he has a concrete and scientific concept of mass."

It was in addition urged that by teaching the absolute units the physics teacher has an opportunity to do a real service to the college. It would be a real service to the college if the secondary school teachers would send to the colleges young men and women with clear and definite concepts and with a training in habits of scientific thinking, rather than with memories crammed with words and verbal definitions. That the secondary schools are not doing this real service under the present system of "absolute" teaching, is shown by the fact that 70 per cent. of the candidates in physics fail in the written examination of the college entrance board. And how about the 90 per cent. of the high-school pupils who do not go to college? Are the secondary schools doing a "real service" to them in launching them on life with a fullness of word definitions and an emptiness of definite and useful information concerning the physical world about them?

I can not help wondering how long the absolute physics will be defended on the grounds that it gives "mental discipline," that it pleases the colleges, and that it furnishes data needed by the expert physicist. Even if these claims were true, that defense has been torn to shreds in the battle over Latin; which was claimed to give "mental discipline," to please the colleges, and to furnish data needed by the professional theologian. There is certainly something in physical science for everybody, and it is equally certain that that something is not to be gained from any catechism of questions on watts, joules, ergs, dynes, etc.

Although I am convinced myself, after having tried the experiment, that the elementary physics should not attempt to teach the absolute units, I would not for an instant advocate any system of regulations by which the use of these units was prohibited. There are many able and sincere teachers who honestly believe in their use, and such teachers should not be prevented from using them. On the other hand, those who do not believe in them, who have found by their experiences that it is useless to try to teach them to their pupils, should not be compelled to do so by regulations aimed at securing uniformity and enforced by an

[6] *Mathematical Gazette*, January, 1909, p. 7.

authority outside the school. This is an excellent example of the way in which such regulations effectively block progress by prohibiting the teacher who would study education scientifically from trying experiments, thus dwarfing him as a science teacher by barring him from applying scientific methods to the study of his teaching problem. Until differences of this sort have been settled by experiment, it is irrational and very injurious to the students to make regulations that decide such questions in advance on *a priori* grounds.

This deductive, logical, abstract, defining-without-concept habit in present physics teaching has been inherited direct from Newton. It is a habit of which Professor Perry says:[7]

> I take it that the method of study into which Newton was forced, became, because of Newton, the favorite English mathematical study, and we know that it kept English mathematicians back for a hundred years. In the shape of elementary deductive geometry, it is keeping back every schoolboy now.

What does this mean? You recall that Newton, when he presented some of his optical discoveries to the Royal Society in 1672, was attacked by Hooke and others and drawn into quite a controversy. This was very distasteful to Newton; and so, before presenting his "Principia," he put it into such form that it would be unassailable. Euclid being the model of such necessary reasoning, this was his model. So we find that the "Principia" begins with definitions, axioms, scholia and the other paraphernalia of geometry. But it is very clear that Newton did not reach his definitions in any such way. They gradually developed in his mind as the result of long pondering over the phenomena, the experiments, and the known data of mechanics. Any one of you who has seriously tried to grasp the real meaning of his justly celebrated "laws or axioms of motion," or who has read and pondered over the voluminous literature that has been written about them, can not fail to be impressed with the mighty genius of the man who first formulated them. It was a very great feat of the scientific imagination. And yet we expect the average high-school pupil to repeat that feat in three or four lessons, and to have facility in the solution of abstract problems involving these definitions in less than a year! And this without having given him the full experimental basis for those laws nor having taught him to ponder scientifically so that he can follow the reasoning by which Newton reached his conclusions.

I have already shown that in England this fallacy of logical perfection in elementary physics has been exposed at the hands of Professor Perry. In Germany the same is true. That celebrated commission that has been studying this matter there adopted as one of its theses with regard to physics the following: "In teaching, physics must not be treated as a mathematical science, but as a natural science." The meaning of this is given in the following words:

> The specific value of the teaching of physics for general culture has long been diminished because of the fact that physics is treated primarily as a mathematical science. The chief reason for this is that physics itself has long regarded it as an ideal to present itself in deductive form after the manner of a mathematical system. This is particularly true of the fundamental portion of physics, the mechanics, the construction of which on a few axioms has been regarded as its chief excellence.

I am glad to be able to say that the latest and best of the German elementary texts—that of Poske—does not contain Newton's second law of motion or the absolute system. Professor Poske is editor of the *Journal for Physics Teaching*, a member of the celebrated commission and a teacher of long experience. The book is written for classes that correspond to those

[7] *Mathematical Gazette*, January, 1909, p. 5.

in the second and third years of our high schools. The book has been received with great approbation by the German teachers. Thus although we are ahead of our colleagues across the water in the matter of laboratory equipment, they are, in my opinion, far ahead of us in their knowledge and practise of sound pedagogy.

The essential distinction that I have been endeavoring to make plain between vigor and rigor, between intuition and logic, between concrete and abstract, between relative and absolute, between interest with true discipline and duty with martial rule, has been pointed out for mechanics most clearly by Professor Henri Poincaré in his "Science and Hypothesis,"[8] as follows:

> The principles of mechanics, then, present themselves to us under two different aspects. On the one hand, they are truths founded on experiment and approximately verified so far as concerns almost isolated systems. On the other hand, they are postulates applicable to the totality of the universe and regarded as rigorously true. If these postulates possess a generality and a certainty which are lacking to the experimental verities whence they are drawn, this is because they reduce in the last analysis to a mere convention which we have the right to make, because we are certain beforehand that no experiment can contradict it. This convention, however, is not absolutely arbitrary; it does not spring from our caprice; we adopt it because certain experiments have shown us that it would be convenient. Thus is explained how experiment can make the principles of mechanics, and yet why it can not overturn them.

Hence the particular part of the physics teacher's problem now before us reduces to this: The present system of teaching physics in its elementary stages fails because of its leaning toward rigor, logic, the abstract, the absolute and martial law: the problem is to change the methods of teaching so that vigor, intuition, the concrete, the relative and true discipline shall prevail. One suggestion has already been made as to ways of doing this, namely, *omit the absolute units.* In closing let me throw out two further hints that may assist those who wish to take part in the housecleaning that is at hand.

[8] English translation, p. 98.

Physics is suffering from lack of unity in the way it is presented to beginners. This may be remedied by a suitable use of the idea of energy. In a recent address at the University of Chicago, Professor G. H. Mead showed that the doctrine of energy plays in physical science the same rôle as does the doctrine of evolution in biological science, since it furnishes concepts and a terminology in which all forms of physical phenomena may be expressed. This terminology and these concepts are particularly useful, because they are derived from the idea of mechanical work, which is one of the most immediate and familiar of the concepts drawn from daily experiences. Most commercial accounts are ultimately balanced in terms of work or energy.

In using the idea of energy as a solvent for unifying and organizing instruction in physics it is not in the least necessary to become an "Energetiker," to deny the existence of everything but energy, and to rule out the imagination and speculation concerning atoms and the like. The idea is one easily grasped by any one, since it is drawn from such universal experience. It can be visualized in the lifting of heavy objects so as to be made very concrete. In my opinion this idea offers a fruitful field for experimentation in the teaching of the elements of physics.

Another fruitful suggestion has been made by Dr. Northrup in the *Journal of the Franklin Institute* for March, 1908. It is to use analogy—not poetic analogy, but strict analogy, such as exists between translatory and rotary motion. This same suggestion was made by Professor Henry Crew at the meeting of the Central Association of Science and Mathematics Teach-

ers last November. It is a suggestion well worth considering.

Has not the time now come when we physics teachers of America should begin experimenting with a purpose of trying to discover the live way of teaching our subject? Are we not now ready to right-about-face, and, instead of trying to make our concrete material abstract and mathematical—instead of trying to teach Newton's absolute time and space and motion—to try to make mathematics and the absolute concrete and real through physics? Shall we not take up the movement now being pushed so successfully by Perry and Armstrong in England, by Klein and Poske in Germany and by the brothers Poincaré in France, and push it along in free and progressive America as well? Surely the time is at hand when the work will be done. Let us therefore all lay hold and help, for better times are coming. C. R. Mann

The University of Chicago

ALBERT B. PORTER

Albert Brown Porter was born at Indianapolis on March 16, 1864, and died at Chicago on April 16, 1909. He was a man of rare endowment, well known to many of the readers of this journal. Since, however, his published researches are comparatively few in number, he was by no means so widely known as his native abilities would ordinarily have made him.

His preparation for college, obtained at the Indianapolis High School, enabled him to enter Stevens Institute at the early age of fifteen. Most of the best training of this precocious lad was, however, obtained in his own home and at the hands of his own father, Albert G. Porter, who was governor of Indiana during the early eighties. From this period dates his acquisition of an almost faultless English style and the beginning of his acquaintance with tools and with the properties of matter. In 1882 he migrated to Purdue University, where he graduated B.S. in 1884.

The Richmond, Ind., High School was fortunate in securing the services of this modest, scholarly and skillful young man during the seven years immediately following his graduation. More than one of his students have testified to his inspiring influence and to the manner in which he helped rapidly to upbuild this institution.

In 1891 he went to Baltimore to pursue, under Rowland, Franklin and Newcomb, the subject of physics to which from earliest boyhood he had been devoted. His fellow students still recall that judicial, alert and independent attitude of mind displayed by him regarding all subjects. Pure science being his ruling passion, the atmosphere of Johns Hopkins University was more congenial to him than any other which he subsequently found.

It was during this period that he was married to Miss Therese Study, whom he had first learned to know as a student in the Richmond High School.

In 1894 he accepted appointment to the chair of physics in the then recently founded Armour Institute. It seems almost needless to add that the department was at once placed upon a high plane. His lectures were beautifully illustrated with many novel experiments and were always set forth in that clear English which can result only from clear thinking. Characteristic of the man is a summer spent with Mr. O. L. Petitdidier in learning the technique of lens grinding, figuring and polishing. After eight years' experience in teaching technical students he resigned in order to take up the manufacture and importation of high-grade physical apparatus, operating under the name of "The Scientific Shop." But we must not imagine that Professor Porter ceased to teach when he entered upon the commercial side of his work. On the contrary, his clientele became larger and more advanced, being composed mainly of instructors in physics from all parts of the country; for, being a man of cultivated curiosity and lucid expression, he had satisfaction not only in gathering information, but also in freely imparting knowledge.

His published papers relate chiefly to the diffraction theory of microscopic vision and